GIDA
THE JOURNAL OF FOOD
E-ISSN 1309-6273, ISSN 1300-3070

Research/Araştırma
GIDA (2023) 48 (2) 243-255
doi: 10.15237/gida.GD22081

PHYSICOCHEMICAL, SENSORY, AND BIOACTIVE PROPERTIES OF GLUTEN-FREE PUDDINGS PRODUCED WITH ARONIA DERIVATIVES

Fundagül Erem*
Zonguldak Bülent Ecevit University, Faculty of Engineering, Department of Food Engineering, Zonguldak, Türkiye

Received /Geliş: 25.08.2022; *Accepted* / Kabul: 04.02.2023; *Published online* / Online baskı: 10.02.2023

Erem, F. (2023). Physicochemical, sensory, and bioactive properties of gluten-free puddings produced with aronia derivatives GIDA (2023) 48 (2) 243-255 doi: 10.15237/ gida.GD22081

Erem, F. (2023). Aronya türevleri ile üretilen glutensiz pudinglerin fizikokimyasal, duyusal ve biyoaktif özellikleri. GIDA (2023) 48 (2) 243-255 doi: 10.15237/ gida.GD22081

ABSTRACT
This study aimed to investigate the properties of gluten-free puddings, in which antioxidant activity was enhanced by adding aronia powder and aronia fiber powder. The coconut flour in the control sample was partially substituted with aronia derivatives at 0.25%, 0.5%, and 1.0% concentrations. Increasing the substitution levels resulted in a decrease in Brix, L*, and b* values, and an increase in the a* and ΔE* values, total phenolic content and antioxidant activity of the puddings ($P <0.05$). The results obtained showed that the highest concentrations of aronia derivatives substantially ($P <0.05$) increased the syneresis index; however, there were no significant differences at low substitution levels. Besides, aronia derivatives did not cause a substantial change in the sensory properties of the puddings, except for the consistency in the mouth. Since coconut flour and aronia were found compatible with each other sensorily, they may be valorized together in the development of different food products.
Keywords: Aronia, coconut flour, gluten-free, pudding

ARONYA TÜREVLERİ İLE ÜRETİLEN GLUTENSİZ PUDİNGLERİN FİZİKOKİMYASAL, DUYUSAL ve BİYOAKTİF ÖZELLİKLERİ

ÖZ
Bu çalışma aronya tozu ve aronya lifi tozu ilave edilerek antioksidan aktivitesi artırılan glutensiz pudinglerin özelliklerini araştırmayı amaçlamıştır. Kontrol örneğindeki hindistan cevizi unu, aronya türevleri ile %0.25, %0.5 ve %1.0 konsantrasyonlarında kısmen ikame edilmiştir. İkame seviyesinin artırılması örneklerin Briks, L*, ve b* değerinde azalışa, a* ve ΔE* değeri, toplam fenolik madde içeriği ve antioksidan aktivitesinde artışa yol açmıştır ($P <0.05$). Elde edilen sonuçlar, aronya türevlerinin en yüksek konsantrasyonunun sinerez indeksini önemli ölçüde ($P <0.05$) artırdığını; ancak düşük ikame seviyelerinde önemli bir farklılık olmadığını göstermiştir. Ayrıca, aronya türevleri ağızdaki kıvam dışında, pudinglerin duyusal özelliklerinde önemli bir değişikliğe neden olmamıştır. Hindistan cevizi unu ve aronya türevlerinin birbirleriyle duyusal olarak uyumlu oldukları bulunduğundan, bunlar farklı gıda ürünlerinin geliştirilmesinde birlikte değerlendirilebilirler.
Anahtar kelimeler: Aronya, hindistan cevizi unu, glutensiz, puding

* *Corresponding author* / Yazışmalardan sorumlu yazar
✉: fundagulerem@beun.edu.tr ☏: (+90) 372 291 2630 🖷: (+90) 372 257 4023

Fundagül Erem; ORCID no: 0000-0003-1562-0686

INTRODUCTION

Gluten is a protein complex, composed of two fractions called glutenin and gliadin, which is found in certain cereals such as wheat, rye, and barley. It is an important compound that determines the technological properties of bakery products thanks to its ability to form a three-dimensional protein network (de Lorgeril and Salen, 2014; Šmídová and Rysová, 2022). On the other hand, there are also some health issues derived from gluten. According to the terminology and classification proposed in a conference held in London in February 2011, celiac disease (CD), gluten ataxia, dermatitis herpetiformis, wheat allergy, and non-celiac gluten sensitivity are the gluten-related disorders (Sapone et al., 2012; Tovoli et al., 2015). The most well-known gluten-related disorder, CD, which has an increasing prevalence rate worldwide, is a common immune-based disorder triggered by gluten intake, especially in genetically predisposed individuals (Gatti et al., 2020). Apart from CD, there is also an increase in the number of individuals suffering from non-celiac gluten sensitivity and wheat allergy (Mansueto et al., 2014). The treatment that could be applied for gluten-related disorders is to follow a gluten-free diet. Except for people who suffer from gluten-related disorders, there is also a growing increase in the number of healthy individuals adopting gluten-free nourishment as a lifestyle (Sabença et al., 2021). Therefore, developing gluten-free products which are acceptable to consumers, and have gained functional properties, is becoming the interest of food manufacturers, scientists, and health professionals dramatically (Khoury et al., 2018).

Even though there is not a commonly recognized definition, functional foods are generally defined as processed or natural foods that have potentially positive effects on health when consumed regularly, beyond basic nutrition. They may reduce the risk of noncommunicable diseases. However, to be regarded as functional, their safety and functionality should be proved by clinical and experimental trials and should be compatible with the regulations of the country (Granato et al. 2020, Alongi and Anese 2021). One of the most important issues regarding the functional foods is since they do not heal or prevent diseases, they should not be qualified as medications. The most described and studied functional ingredients are polyunsaturated fatty acids, probiotics, prebiotics, synbiotics, and antioxidants (Granato et al. 2020).

Coconut flour is generally obtained by milling the residue of the coconut which remains after the extraction of coconut milk and the subsequent defatting process (Bawalan, 2000; Gunathilake et al., 2009). According to another procedure, it may also be produced without the defatting process (Hopkin et al., 2022). Coconut flour is rich in dietary fiber, which makes it a potential functional food (Trinidad et al., 2006), is gluten-free, has a comparable protein content to wheat (Ramaswamy, 2014), and is also free of trans-fatty acids (Adeloye et al., 2020). It can be used in the production of several products such as bread, cookies, cake, noodles, and desserts, either alone or blended with other flour samples up to a certain level, and as a filler and bulking agent in the products (Gunathilake and Abeyrathne, 2008).

Fruits in the berries class are known as rich in phenolic compounds, which exhibit high antioxidant activity (Oszmiański and Wojdylo, 2005). In several studies, aronia (*Aronia melanocarpa*), known as black chokeberry, has also been reported to have high antioxidant activity, which arises from its phenolic compounds (Oszmiański and Wojdylo, 2005; Gralec et al., 2019; Meng et al., 2019; Rodríguez-Werner et al., 2019; Banach et al., 2020). Due to its bioactive compounds, especially phenolic compounds, aronia also has antidiabetic, antimutagenic, hepatoprotective, and immunomodulatory properties and may be beneficial for health by protecting against several chronic diseases such as heart diseases, cancer, diabetes, etc. (Kulling and Rawel, 2008; Gajic et al., 2020). Its functional properties make aronia a good candidate for using it, its powder, or other derivatives as an ingredient in foods, juices, and drinks (Du and Myracle, 2018; Rodríguez-Werner et al., 2019; Vidović et al., 2019).

Several studies on the usage of coconut flour in the production of bread (Gunathilake et al., 2009), biscuits (Jiamjariyatam et al., 2021), cookies (Paucean et al., 2017; Marikkar et al., 2020), noodles (Gunathilake and Abeyrathne, 2008), cake (Hopkin et al., 2022), snacks (Mihiranie et al., 2017), or breakfast cereal (Okafor and Usman, 2014; Usman and Okafor, 2016) are available. Coconut flour was generally used as a dietary fiber source and the compositional, textural, and sensory qualities of the products were determined in these studies. It was reported that using coconut flour up to a certain level depending on the product type was found advantageous and feasible. However, no study that valorized coconut flour as the main thickening agent in pudding production could be found. On the other hand, only one study could be found in the literature that used aronia extract in puddings (Lee and Choi, 2020), and one used aronia juice concentrate in agar gels (Jakubczyk and Kamińska-Dwórznicka, 2021); however, there were no data for total phenolic or antioxidant activity in these studies. Due to the consumer demand for healthy foods, the aim in this study was to produce an acceptable coconut flour-based gluten-free pudding in which antioxidant activity was enhanced by the addition of aronia powder (AP) and aronia fiber powder (AFP) at different substitution levels.

MATERIALS AND METHODS

Materials

The ingredients used for the pudding production were: coconut flour (Değirmencibaşı, Smart Kimya, İzmir, Türkiye), xanthan gum (Tito, Smart Kimya, İzmir, Türkiye), freeze-dried aronia powder (Mor Aronya Gıda ve Sağlık, İstanbul, Türkiye), aronia fiber powder (100% micronized organic aronia pulp; Mor Aronya Gıda ve Sağlık, İstanbul, Türkiye), UHT milk (İcim, Türkiye), and granulated refined sugar (Migros, Türkiye). The composition of the ingredients specified by the manufacturers are shown in Table 1. All the chemicals used for the analysis were of analytical grade.

Table 1. Nutritional values of the ingredients

	Coconut flour (g/100g)	AP (g/100g)	AFP (g/100g)	UHT milk (g/100ml)
Carbohydrate	64.0	73.0	13.61	4.7
-Sugar	18.7	41.0	1.11	N
Protein	19.0	2.5	6.94	3.0
Fat	16.0	1.0	3.61	3.0
-Saturated fat	3.0	0.0	0.28	3.0
Fiber	N	19.0	70.0	-

The data given in the table were obtained from the product labels.
N: not declared;

Methods

Preparation of puddings

The composition of the pudding samples is given in Table 2. All the dry ingredients were added to the UHT milk, and the mixture was heated with continuous stirring. Cooking was terminated after 5 min of boiling and cooked puddings were transferred into small cups before cooling. After cooling at room temperature, pudding samples were stored at 4 °C overnight before analysis.

In preliminary studies, it was determined that coconut flour was adequate for gelation, however; xanthan gum was also used in the formulation since it made the puddings smoother. Since coconut flour was the primary thickening agent in the formulation, substituting the coconut flour with higher AP and AFP concentrations than 1.0% affected the storage stability and consistency adversely. Therefore, 1.0% was determined as the maximum inclusion level for both AP and AFP.

Table 2. The composition of the pudding samples (g/100g)

	C	AP1	AP2	AP3	AFP1	AFP2	AFP3
UHT milk	81.8	81.8	81.8	81.8	81.8	81.8	81.8
Coconut flour	8.00	7.75	7.50	7.00	7.75	7.50	7.00
Sugar	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Xanthan gum	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Aronia powder	-	0.25	0.50	1.0	-	-	-
Aronia fiber powder	-	-	-	-	0.25	0.50	1.0

C, control sample; AP, samples containing aronia powder; AFP, samples containing aronia fiber powder

Physicochemical properties of puddings

Total soluble solids content. The method of Lee and Choi (2020) was slightly modified for the determination of total soluble solids. Twenty grams of sample was mixed with 40 ml of distilled water and agitated at 130 rpm for an hour at room temperature. Then the mixture was transferred into centrifuge tubes and centrifuged (3000 × *g*, 4 °C) for 20 min (Nuve NF 800R, Ankara, Türkiye). The supernatants were filtered through a filter paper (4–7 μm pore size) and the total soluble solids content (°Brix) was measured with a refractometer (RHB-80ATC, USA).

Color. The color of the puddings was measured using a spectral colorimeter (CHN CS-410, China) with a D65 illuminant and an observing angle of 10°, and expressed using CIELab parameters (L*, a*, b* values). A white plate was used as the calibration standard (L* = 98.55, a* = 0, b* = 1.32). The measurements for each formulation were made on five different points of three puddings. The total color difference (ΔE*) between the control pudding (C) and the aronia-enriched puddings (A) was also calculated using equation (1) (Baixauli et al., 2008). The formulas used for calculating the hue angles considering the different quadrants to express the hue angle as positive numbers (McLellan et al., 1995) are shown in equation (2a-c).

$$\Delta E^* = [(L_C{}^* - L_A{}^*)^2 + (a_C{}^* - a_A{}^*)^2 + (b_C{}^* - b_A{}^*)^2]^{1/2} \quad (1)$$

1st quadrant (+a*, +b*)

$$h° = ArcTan(b*/a*) \quad (2a)$$

2nd quadrant (-a*, +b*) and 3rd quadrant (-a*, -b*)

$$h° = 180 + ArcTan(b*/a*) \quad (2b)$$

4th quadrant (+a*, -b*)

$$h° = 360 + ArcTan(b*/a*) \quad (2c)$$

Syneresis index. The syneresis index of the puddings was determined by the method of Valencia et al. (2016) with some modifications. Pudding samples of 15 g were weighed into a 50 ml centrifuge tube and centrifuged at 3000 × *g* for 30 min at 5 °C. The syneresis index was expressed as a percentage by dividing the supernatant weight by the sample weight.

Storage stability. Ten grams of pudding sample in a pre-weighed plastic cup was stored at 4 °C for 72 h after being wrapped with aluminum foil. Next, the leaching water was removed, and the cup was re-weighed. The ratio of the final weight of the sample to the initial weight of the sample as a percentage was evaluated as the storage stability (Moin et al., 2017).

Total phenolic content and antioxidant activity of puddings

Extraction of the pudding samples and analysis of antioxidant activity were done according to the methods of Sun et al. (2007) with some modifications. Pudding samples of 10 g were mixed with 20 ml of 99.8% ethanol, and vortexed for approximately 30 s until a homogenized mixture was obtained. Then, the mixture was centrifuged at 3000 × *g* for 10 min (Nuve NF 800R, Ankara, Türkiye), and the supernatant was filtered through a quantitative filter paper of 4–7 μm pore size. Supernatants were maintained at −20 °C until the analyses were performed. Dilutions of the extracts were made with 75% ethanol, and 75% ethanol was also used as blank.

Total phenolic content. The extract (250 μl) was mixed with 1250 μl of Folin–Ciocalteu's phenol reagent (10-fold diluted with distilled water, v/v) and 1000 μl of 7.5% sodium carbonate and incubated at 50 °C for 15 min in a dark place, which was followed by measuring the absorbance with a spectrophotometer (Shimadzu UV-1800, Kyoto, Japan) at 750 nm for the determination of total phenolic content (Ramírez-Maganda et al., 2015). Results were calculated as mg gallic acid equivalent/100 g sample by using a calibration curve ($y=11.176x+0.0038$, $R^2 = 0.9994$) generated with the gallic acid standard (5-60 mg/L).

DPPH analysis. The DPPH (2,2-diphenyl-1-picrylhydrazyl) assay was carried out by mixing 2 ml of extract or Trolox standard (6-40 μM) with 350 μl of 0.5 mM DPPH solved in 99.8% ethanol, and measuring the absorbance value at 517 nm with a spectrophotometer (Shimadzu UV-1800, Kyoto, Japan) after 30 min incubation at room temperature.

ABTS analysis. To perform the ABTS (2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid)) assay, ABTS•+ radical, which was generated by holding the 7 mM ABTS stock solution containing 2.45 mM potassium persulfate for 12–16 h at room temperature, was diluted with 99.8% ethanol to an absorbance of 0.70 ± 0.02 at 734 nm. Then, 900 μl of ABTS•+ radical was mixed with 100 μl of extract or Trolox standard (10-280 μM), and the absorbance was measured at 734 nm after 6 min from initial mixing.

The scavenging effect was calculated with equation (3) and using the calibration curve ($y=2.4966x-6.6229$, $R^2 = 0.9994$ for DPPH, and $y=0.2994x+7.2901$, $R^2 = 0.9998$ for ABTS methods) obtained with the Trolox standard; antioxidant activity results are given as mg Trolox equivalent/100 g sample.

$$Scavenging\ effect\ (\%) = \frac{Abs_{blank} - Abs_{sample}}{Abs_{blank}} x100 \quad (3)$$

Sensory analysis of puddings

Sensory evaluation was carried out by 13 untrained panelists comprising male and female undergraduate students and staff in the Faculty of Engineering at Zonguldak Bülent Ecevit University; the pudding samples were coded with random letters. Panelists were asked to grade puddings with a 5-point hedonic scale ranging from 1 (dislike extremely) to 5 (like extremely) for each parameter. The parameters were color, taste, odor, consistency (both appearance and in the mouth), and overall appreciation (Gurmeric et al., 2013; Moin et al., 2017).

Statistical analysis

The effect of the substitution level of AP and AFP on the response values (Brix, color, syneresis index, total phenolic content, antioxidant values, sensory analysis) of the pudding samples was evaluated. The statistically significant differences between the pudding samples were analyzed by performing an analysis of variance (ANOVA) on data using SAS System Software (SAS OnDemand for Academics). The parameters determined as significant at the 95% confidence level were evaluated by Duncan's multiple range test. All experiments were performed in three replicates and the results of the analysis were given as mean ± standard error. Pearson's correlation coefficients (r) between variables were determined with Minitab Statistical Software (Academic version, Minitab Inc. USA).

RESULTS AND DISCUSSION

Physicochemical properties

The total soluble solids content (Brix) and color values of the pudding samples in which coconut flour was partially substituted with AP (aronia powder) and AFP (aronia fiber powder) are shown in Table 3. Increasing the substitution level resulted in a decrease in Brix value and the difference was statistically significant when compared to the control sample ($P < 0.05$). This was probably related to the decrease in the amount of coconut flour in the formulations including AP or AFP. Distinctly from this study, Lee and Choi (2020) determined an increase in the total soluble solids content of puddings with increasing aronia concentration. However, they decreased the amount of milk on increasing the aronia concentration and did not change any other solid ingredient in their formulation.

Table 3. Total soluble solids content and color values of pudding samples.

	Brix (°Bx)	L*	a*	b*	ΔE*	h*
C	$7.83^{a} \pm 0.17$	$86.61^{a} \pm 0.44$	$-0.77^{d} \pm 0.03$	$11.86^{a} \pm 0.09$	-	$93.71^{b} \pm 0.15$
AP1	$7.00^{b} \pm 0.00$	$73.01^{b} \pm 0.11$	$4.18^{c} \pm 0.04$	$3.24^{c} \pm 0.05$	$16.85^{f} \pm 0.10$	$37.77^{d} \pm 0.38$
AP2	$6.57^{c} \pm 0.07$	$65.47^{d} \pm 0.19$	$5.46^{b} \pm 0.08$	$1.08^{f} \pm 0.06$	$24.54^{d} \pm 0.25$	$11.17^{f} \pm 0.60$
AP3	$6.50^{c} \pm 0.00$	$58.50^{f} \pm 0.09$	$6.42^{a} \pm 0.06$	$-1.10^{g} \pm 0.03$	$31.78^{b} \pm 0.10$	$350.27^{a} \pm 0.29$
AFP1	$7.00^{b} \pm 0.00$	$68.75^{c} \pm 0.19$	$4.35^{c} \pm 0.04$	$3.57^{b} \pm 0.04$	$20.35^{e} \pm 0.27$	$39.36^{c} \pm 0.34$
AFP2	$6.67^{c} \pm 0.17$	$60.39^{e} \pm 0.23$	$5.56^{b} \pm 0.06$	$2.40^{d} \pm 0.05$	$28.58^{c} \pm 0.54$	$23.36^{e} \pm 0.39$
AFP3	$6.57^{c} \pm 0.07$	$51.94^{g} \pm 0.22$	$6.40^{a} \pm 0.04$	$1.31^{e} \pm 0.03$	$36.94^{a} \pm 0.51$	$11.57^{f} \pm 0.23$

C, control sample; AP1, AP2, and AP3, samples containing 0.25%, 0.5% and 1.0% aronia powder, respectively; AFP1, AFP2, and AFP3, samples containing 0.25%, 0.5% and 1.0% aronia fiber powder, respectively. Results are given as mean ± standard error.

Means with a different superscript letter within a column indicate significant differences ($P < 0.05$) among the samples.

The L*, a*, and b* values represent darkness–lightness (from 0 to 100), greenness–redness (from negative to positive), and blueness–yellowness (from negative to positive), respectively (Durmus, 2020). The addition of increasing levels of AP or AFP made the puddings darker (P <0.05) and caused an increase in the redness (P <0.05) and a decrease in the yellowness (P <0.05) of the puddings. The results were similar to the findings of Lee and Choi (2020), who observed lower L* and b*, and higher a* values with an increasing concentration of aronia extract. It was observed that the effect of AFP on the darkness of the puddings was substantially larger (P <0.05) than that of AP, and the yellowness of the AFP-containing puddings was higher (P <0.05) at the same substitution level. According to the manufacturer's declaration, AP is produced by grinding the freeze-dried whole fruit. On the other hand, AFP is produced by drying and grinding the remained aronia pulp at a low temperature after the fruit juice is obtained. The darker color for AFP-containing puddings probably arose from drying process applied. Chen and Martynenko (2018) also determined lower L* values for blueberry leathers dried from two different purees using forced air drying compared to the freeze-drying method. The color difference of the puddings was statistically significant (P <0.05) and increased with an increasing AP or AFP concentration. It was determined that AFP is more effective than AP in increasing the color difference. The red color is represented by the hue angles of 0° and 360° while the yellow, green, and blue colors are represented by the 90°, 180°, and 270°, respectively (Milovanovic et al., 2020). The hue angles are given in Table 3. These values showed that the control sample had a yellowish color while AP and AFP-containing samples had reddish colors. Images of the pudding samples are given in Figure 1.

The results for the syneresis index of puddings are shown in Figure 2. The control sample showed no syneresis. However, syneresis was observed for AP- and AFP-containing samples, probably due to the decrease in starch and fiber content, which was caused by lowering the amount of coconut flour. The effect of AP and AFP at lower concentrations (0.25% and 0.5%) on the syneresis index of puddings was not statistically significant and could be considered as negligible. On the other hand, the syneresis indices were calculated as 6.26% and 12.14% for AP- and AFP-containing samples at the concentration of 1%, respectively (P <0.05). Puddings are generally known as milk protein-based starch paste (Lim and Narsimhan, 2006). The reorganization of the starch or retrogradation during gel or paste formation is the main cause of syneresis (Ribotta et al., 2012) and the syneresis phenomenon occurs as a result of the loss of unbound water (da Silva Costa et al., 2020). According to the manufacturer's declaration on the packages, the fiber content of AFP is approximately 3.7-fold higher than that of AP, and AP contains 2.6-fold more sugar (Table 1). AFP was expected to bind water more than AP due to its fiber content. However, the higher sugar content of AP might have prevented starch retrogradation to some extent (Dello Staffolo et al., 2017), thus giving more positive results in terms of syneresis. Moreover, it has also been reported that chokeberry fiber increases the syneresis in fermented milk samples since its dietary fiber is poorly soluble and its tannins may precipitate proteins (Szajnar et al., 2021).

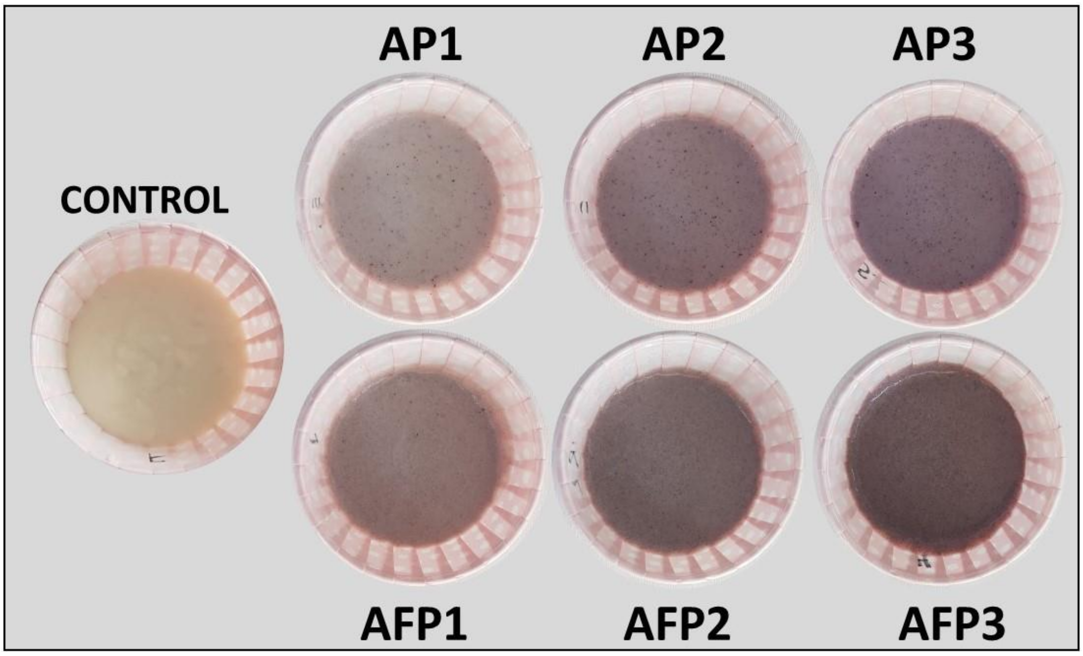

Figure 1. Pudding samples after held in a refrigerator overnight. AP1, AP2, and AP3, samples containing 0.25%, 0.5% and 1.0% aronia powder, respectively; AFP1, AFP2, and AFP3, samples containing 0.25%, 0.5% and 1.0% aronia fiber powder, respectively.

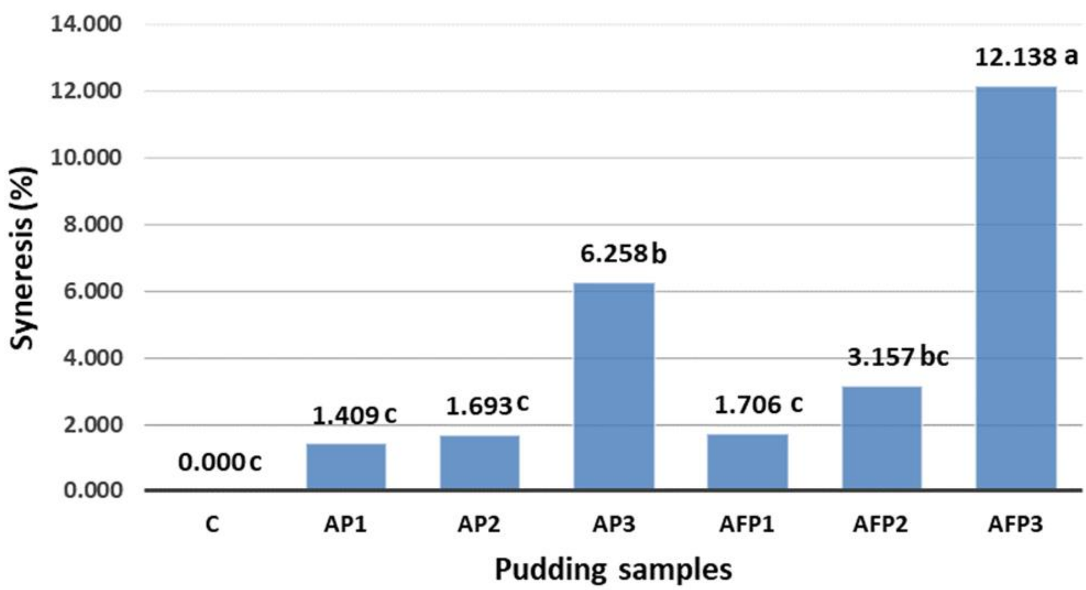

Figure 2. Syneresis index of pudding samples. Different lowercase letters shown with mean values represent significant differences (*P <0.05*). AP1, AP2, and AP3, samples containing 0.25%, 0.5% and 1.0% aronia powder, respectively; AFP1, AFP2, and AFP3, samples containing 0.25%, 0.5% and 1.0% aronia fiber powder, respectively.

Good storage stability is an important indicator to obtain preferable puddings (Lim and Narsimhan, 2006). While syneresis is calculated depending on the water released from samples under centrifugal forces, storage stability is calculated according to the water expelled from a paste after refrigeration or the freeze–thaw cycle (Moin et al., 2017). The storage stability of the puddings was determined after 72 h storage at 4 °C. For each formulation, three different cups were used for the analysis. After storage, free water was observed only in one cup for AP3 and AFP2, and in two cups for AFP3. The storage stability was calculated as 3.2%, 3.1%, and 4.2% for the mentioned samples, respectively, and the pudding samples could be considered to have good storage stability.

Total phenolic content and antioxidant activity of puddings

The total phenolic content and antioxidant activity results of the pudding samples are shown in Figure 3. It was found that increasing the concentration of AP or AFP increased the total phenolic content and antioxidant activity of the samples significantly ($P < 0.05$). In addition, the effect of AP on the mentioned values was higher than that of AFP. AP3 was determined to have the highest total phenolic content and antioxidant activity (with both DPPH and ABTS methods) among the others ($P < 0.05$), with values of 23.77 ± 0.66 mg GAE/100 g sample, 26.91 ± 0.17 mg TE/100 g sample, and 37.18 ± 2.42 mg TE/100 g sample, respectively. AP3 was followed by AFP3 > AP2 >AFP2 > AP1 > AFP1 > C in terms of total phenolic content. However, there were no significant differences between AFP3 and AP2, or between AFP2 and AP1. This result shows that pudding samples had the statistically same total phenolic content when using AP at half the concentration of AFP. In terms of antioxidant activity determined by the DPPH method, the order of samples was AP3, AFP3, AP2, AFP2, AP1, AFP1, and C from highest to lowest value. The order is also the same according to the ABTS method; however, the effect of AP and AFP on antioxidant activity was determined to be statistically the same at 0.25% and 0.50% concentrations.

The heat application in food production is the main handicap to obtaining products rich in antioxidant activity due to the sensitivity of phenolic compounds to heat (Albuquerque et al., 2021); even so, AP or AFP addition resulted in a remarkable increase in the antioxidant activity of the puddings. There were no data for total phenolic or antioxidant activity of aronia-enriched puddings in the literature; however, the antioxidant activity of bakery products (bread, mini baguette, and biscuit) fortified with aronia has been reported to range between 19.1 and 34.2 mg TE/100 g (Catana et al., 2018). Lee and Choi (2016) and Lee and Yoon (2016) found elevated scavenging activity for cookies incorporating an increasing level of AP.

The relationship between total phenolic content, antioxidant activity, aronia concentration, and color values was evaluated with Pearson's correlation (Table 4) and the correlations were found to be strong for both AP- and AFP-containing puddings. It was observed that total phenolic content was highly correlated with antioxidant activity ($P < 0.01$), indicating that the phenolic compounds in the pudding samples were the primary sources of antioxidant activity. Furthermore, DPPH and ABTS results were also positively correlated with each other ($P < 0.01$). The correlation coefficient between total phenolic content and the DPPH test of aronia berries in different stages of development determined by Gralec et al. (2019) ($r = 0.7$) shows them to be positively correlated.

Correlation analysis revealed that there was a strong relation between color values and other parameters (total phenolic content and antioxidant activity). L* and b* values were negatively correlated with other parameters, while a* values were positively correlated. Cömert et al. (2020) reported that the color of fruits and vegetables is compatible with their antioxidant content, and fruits and vegetables containing higher amounts of anthocyanins and total phenols also have a high antioxidant content. They also found that most fruits and vegetables whose hue values are above 180° and below 20° have high antioxidant capacity. When considering the hue angles (Table 3) and antioxidant activity values (Figure 3) together, the results are consistent with the findings of Cömert et al. (2020).

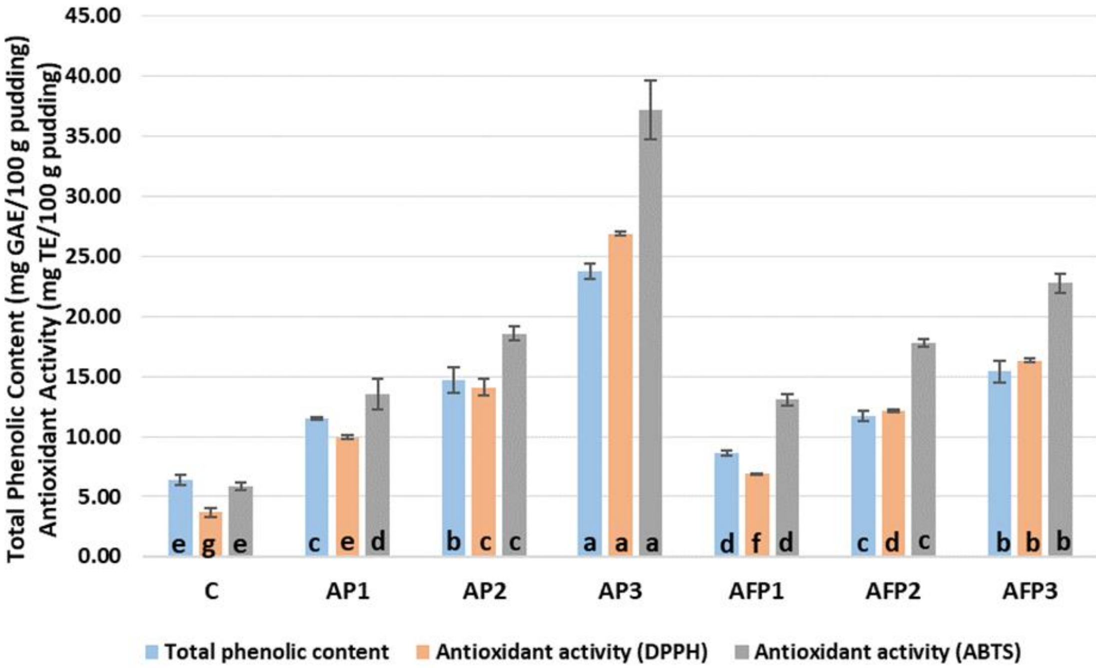

Figure 3. Total phenolic content and antioxidant activity of pudding samples. Different letters for the same-colored bars refer to significant differences (P <0.05) among the samples. AP1, AP2, and AP3, samples containing 0.25%, 0.5% and 1.0% aronia powder, respectively; AFP1, AFP2, and AFP3, samples containing 0.25%, 0.5% and 1.0% aronia fiber powder, respectively.

Table 4. Pearson's correlation coefficients

		Concentration †	TPC	DPPH	ABTS	L*	a*
Aronia Powder	TPC	0.973**					
	DPPH	0.991**	0.967**				
	ABTS	0.965**	0.950**	0.965**			
	L*	-0.949**	-0.919**	-0.950**	-0.890**		
	a*	0.860**	0.832**	0.862**	0.795**	-0.974**	
	b*	-0.878**	-0.851**	-0.880**	-0.816**	0.980**	-0.998**
Aronia Fiber Powder	TPC	0.931**					
	DPPH	0.978**	0.919**				
	ABTS	0.964**	0.878**	0.978**			
	L*	-0.936**	-0.859**	-0.953**	-0.982**		
	a*	0.842**	0.768**	0.868**	0.932**	-0.975**	
	b*	-0.807**	-0.729**	-0.831**	-0.908**	0.957**	-0.996**

TPC:Total Phenolic Content; DPPH:2,2-diphenyl-1-picrylhydrazyl; ABTS: 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid)

†AP or AFP concentration in the formulation of puddings.

**The correlation is statistically significant (P <0.01)

Sensory analysis
Consumer demand for nutritious and functional foods, especially those high in antioxidant activity, has been growing day by day. However, one of the primary properties that affect consumers' acceptance of a food is its sensory characteristics. The sensory properties of pudding samples are shown in Table 5. Although the panelists did not know the ingredients of the puddings at first, except for the aronia, they all perceived the coconut from its distinct flavor. According to raw data, control sample had the highest odor score probably due to this distinct and well-known flavor. As noted above, coconut flour was the primary thickening agent, and replacing the coconut flour with AP and AFP, especially at higher concentrations, probably decreased the starch and dietary fiber content. The effect of this decrease was observed on the syneresis and storage stability of the puddings. Therefore, the control sample was expected to have the highest consistency score. However; no significant differences were observed for the consistency of the appearance while AP-containing samples were determined to have the highest scores in terms of consistency in the mouth. Although there were no statistical differences between the pudding samples except for the parameter consistency in the mouth, AP-containing samples were liked more than AFP-containing samples. Addition of 1% AFP caused a substantial decrease in the consistency score ($P < 0.05$); however, all the samples were found acceptable by the panelists. The panelists expressed that coconut flour and aronia were compatible with each other and they could buy all the puddings in case of being commercial products. Considering the overall appreciation of raw data, AP3 was the most preferred sample, which differs from the results of Lee and Choi (2020) who reported that the overall acceptance score of the puddings was decreased for samples containing more than 0.5% aronia extract. Probably, since coconut flour repressed the astringency of aronia, puddings containing AP and AFP at concentrations of 1% were also liked.

Table 5. Sensory analysis results of pudding samples.

	Color	Taste	Odor	Consistency		Overall appreciation
				Appearance	In mouth	
C	3.92 ± 0.33	3.85 ± 0.27	3.85 ± 0.19	3.77 ± 0.32	3.69^{ab} ± 0.24	3.62 ± 0.29
AP1	3.62 ± 0.29	3.92 ± 0.24	3.69 ± 0.21	3.69 ± 0.18	4.00^{a} ± 0.23	4.00 ± 0.20
AP2	4.00 ± 0.25	3.69 ± 0.29	3.77 ± 0.17	3.69 ± 0.18	3.85^{a} ± 0.25	4.08 ± 0.24
AP3	4.15 ± 0.22	4.15 ± 0.25	3.77 ± 0.17	3.92 ± 0.14	4.00^{a} ± 0.25	4.23 ± 0.26
AFP1	3.69 ± 0.26	3.62 ± 0.18	3.62 ± 0.24	3.54 ± 0.24	3.31^{ab} ± 0.29	3.62 ± 0.18
AFP2	3.54 ± 0.27	3.39 ± 0.27	3.31 ± 0.31	3.39 ± 0.27	3.39^{ab} ± 0.31	3.54 ± 0.27
AFP3	4.15 ± 0.22	3.23 ± 0.34	3.69 ± 0.24	4.00 ± 0.23	2.92^{b} ± 0.37	3.54 ± 0.35

C, control sample; AP1, AP2 and AP3, samples containing 0.25%, 0.5% and 1.0% aronia powder, respectively; AFP1, AFP2 and AFP3, samples containing 0.25%, 0.5% and 1.0% aronia fiber powder, respectively. Results are given as mean ± standard error.
Different letters in a column refer to significant differences ($p<0.05$), which were observed just for consistency in mouth.

CONCLUSION
Consumers show growing interest in functional foods and gluten-free foods for health problems or just aiming for healthy nutrition. Consumer demands for healthy foods have impelled experts to develop novel food products. In this study, gluten-free puddings prepared with coconut flour were evaluated as a control sample and their antioxidant activity was enhanced by substituting the coconut flour with AP or AFP. Although all samples were acceptable sensorily, puddings with added AP were more preferable. Aronia or its derivatives (powder, extract, etc.) when used at the right concentrations could be good ingredients to develop different food products high in antioxidant activity without affecting the product negatively. Future studies could be done intended for determining the shelf-life of the

puddings. Microbiological analyses, textural and rheological measurements in addition to compositional and physicochemical analyses could be carried out for this purpose. Moreover, performing in vitro bioaccessibility studies could be beneficial.

CONFLICT OF INTEREST

The author reports no conflict of interest.

REFERENCES

Adeloye, J.B., Osho, H., Idris, L.O. (2020). Defatted coconut flour improved the bioactive components, dietary fibre, antioxidant and sensory properties of nixtamalized maize flour. *Journal of Agriculture and Food Research*, 2:100042.

Albuquerque, B.R., Heleno, S.A., Oliveira, M.B.P.P., Barros, L., Ferreira, C.F.R. (2021). Phenolic compounds: current industrial applications, limitations and future challenges. *Food and Function*, 12: 14-29.

Alongi, M., Anese, M. (2021). Re-thinking functional food development through a holistic approach. *Journal of Functional Foods*, 81: 104466.

Baixauli, R., Salvador, A., Fiszman, S.M. (2008). Textural and colour changes during storage and sensory shelf life of muffins containing resistant starch. *European Food Research and Technology*, 226: 523-530.

Banach, M., Wiloch, M., Zawada, K., Cyplik, W., Kujawski, W. (2020). Evaluation of antioxidant and anti-inflammatory activity of anthocyanin-rich water-soluble aronia dry extracts. *Molecules*, 25:4055.

Bawalan, D.D. (2000). The economics of production, utilization and marketing of coconut flour from coconut milk residue. *Coconut Research and Development Journal*, 16 (1): 1-13.

Catana, M., Catana, L., Iorga, E., Asanica, A.C., Belc, N. (2018). Bakery products fortified with dried fruits of *Aronia melanocarpa*. *Scientific Papers-Series B-Horticulture*, 62: 693-701.

Chen, Y., Martynenko, A. (2018). Combination of hydrothermodynamic (HTD) processing and different drying methods for natural blueberry leather. *LWT-Food Science and Technology*, 87: 470-477.

Cömert, E.D., Ataç Mogol, B., Gökmen, V. (2020). Relationship between color and antioxidant capacity of fruits and vegetables. *Current Research in Food Science*, 2: 1-10.

da Silva Costa, R.A., Bonomo, R.C.F., Rodrigues, L.B., Santos, L.S., Veloso, C.M. (2020). Improvement of texture properties and syneresis of arrowroot (*Maranta arundinacea*) starch gels by using hydrocolloids (guar gum and xanthan gum). *Journal of the Science of Food and Agriculture*, 100: 3204-3211.

De Lorgeril, M., Salen, P. (2014). Gluten and wheat intolerance today: are modern wheat strains involved? *International Journal of Food Sciences and Nutrition*, 65 (5): 577-581.

Dello Staffolo, M., Sato, A.C.K., Cunha, R.L. (2017). Utilization of plant dietary fibers to reinforce low-calorie dairy dessert structure. *Food and Bioprocess Technology*, 10: 914-925.

Du, X., Myracle, A.D. (2018). Development and evaluation of kefir products made with aronia or elderberry juice: sensory and phytochemical characteristics. *International Food Research Journal*, 25 (4): 1373-1383.

Durmus, D. (2020). CIELAB color space boundaries under theoretical spectra and 99 test color samples. *Color Research & Application*, 45: 796-802.

Gajic, D., Saksida, T., Koprivica, I., Vujicic, M., Despotovic, S., Savikin, K., Jankovic, T., Stojanovic, I. (2020). Chokeberry (*Aronia melanocarpa*) fruit extract modulates immune response in vivo and in vitro. *Journal of Functional Foods*, 66:103836.

Gatti, S., Lionetti, E., Balanzoni, L., Verma, A.K., Galeazzi, T., Gesuita, R., Scattolo, N., Cinquetti, M., Fasano, A., Catassi, C. (2020). Increased prevalence of celiac disease in school-age children in Italy. *Clinical Gastroenterology and Hepatology*, 18 (3): 596-603.

Gralec, M., Wawer, I., Zawada, K. (2019). *Aronia melanocarpa* berries: phenolics composition and antioxidant properties changes during fruit development and ripening. *Emirates Journal of Food and Agriculture*, 31 (3): 214-221.

Granato, D., Barba, F.J., Bursać Kovačević, D., Lorenzo, J.M., Cruz, A.G., Putnik, P. (2020). Functional Foods: Product Development, Technological Trends, Efficacy Testing, and Safety. *Annual Review of Food Science and Technology*, 11: 93-118.

Gunathilake, K.D.P.P., Abeyrathne, Y.M.R.K. (2008). Incorporation of coconut flour into wheat flour noodles and evaluation of its rheological, nutritional and sensory characteristics. *Journal of Food Processing and Preservation*, 32: 133-142.

Gunathilake, K.D.P.P., Yalegama, C., Kumara, A.A.N. (2009). Use of coconut flour as a source of protein and dietary fibre in wheat bread. *Asian Journal of Food and Agro-Industry*, 2 (3): 382-391.

Gurmeric, V.E., Doga, M., Toker, O.S., Senyigit, E., Ersoz, N.B. (2013). Application of different multi-criteria decision techniques to determine optimum flavour of prebiotic pudding based on sensory analyses. *Food and Bioprocess Technology*, 6: 2844–2859.

Hopkin, L., Broadbent, H., Ahlborn, G.J. (2022). Influence of almond and coconut flours on Ketogenic, Gluten-Free cupcakes. *Food Chemistry: X*, 13: 100182.

Jakubczyk, E., Kamińska-Dwórznicka, A. (2021). Effect of addition of chokeberry juice concentrate and foaming agent on the physical properties of agar gel. *Gels*, 7:137-151.

Jiamjariyatam, R., Roskhrua, P., Attiwittayaporn, S. (2021). Effect of coconut flour on biscuit quality. *Journal of Culinary Science and Technology*, 20 (3): 278-292.

Khoury, D.E., Balfour-Ducharme, S., Joye, I.J. (2018). A review on the gluten-free diet: Technological and nutritional challenges. *Nutrients*, 10:1410.

Kulling, S.E., Rawel, H.M. (2008). Chokeberry (*Aronia melanocarpa*) – A review on the characteristic components and potential health effects. *Planta Medica*, 74: 1625-1634.

Lee, J.A., Yoon, J.Y. (2016). The quality and antioxidant properties of cookies containing aronia powder. *Culinary Science & Hospitality Research*, 22 (5): 179-189 [in Korean].

Lee J.H., Choi, J.E. (2016). Quality characteristics and antioxidant activities of cookies supplemented with aronia powder. *Journal of the Korean Society of Food Science and Nutrition*, 45 (7): 1071-1076 [in Korean].

Lee J.H., Choi, I.S. (2020). Physicochemical characteristics and consumer acceptance of puddings fortified with *Cudrania tricuspidata* and *Aronia melanocarpa* extracts. *Food Science and Nutrition*, 8: 4936–4943.

Lim, H.S., Narsimhan, G. (2006). Pasting and rheological behavior of soy protein-based pudding. *LWT-Food Science and Technology*, 39: 343-349.

Mansueto, P., Seidita, A., Dalcamo, A., Carroccio, A. (2014). Non-celiac gluten sensitivity: literature review. *Journal of the American College of Nutrition*, 33 (1): 39-54.

Marikkar, J.M.N., Nagaraja, R., Somawathie, K.M.S., Hewapathirana, H.P.T.D., Yalegama, C., Littardi, P., Chiavaro, E. (2020). Effect of coconut testa flour on cookie characteristics. *Italian Journal of Food Science*, 32 (1): 209-221.

McLellan, M.R., Lind, L.R., Kime, R.W. (1995). Hue angle determinations and statistical analysis for multiquadrant Hunter L, a, b data. *Journal of Food Quality*, 18: 235-240.

Meng, L., Zhu, J., Ma, Y., Sun, X., Li, D., Li, L., Bai, H., Xin, G., Meng, X. (2019). Composition and antioxidant activity of anthocyanins from *Aronia melanocarpa* cultivated in Haicheng, Liaoning, China. *Food Bioscience*, 30: 100413.

Mihiranie, S., Jayasundera, M., Perera, N. (2017). Development of snack crackers incorporated with defatted coconut flour. *Journal of Microbiology, Biotechnology and Food Sciences*, 7 (2): 153-159.

Milovanovic, B., Djekic, I., Miocinovic, J., Djordjevic, V., Lorenzo, J.M., Barba, F.J., Mörlein, D., Tomasevic, I. (2020). What is the color of milk and dairy products and how is it measured? *Foods*, 9 (11):1629.

Moin, A., Ali, T.M., Hasnain, A. (2017). Characterization and utilization of hydroxypropylated rice starches for improving textural and storage properties of rice puddings. *International Journal of Biological Macromolecules*, 105: 843-851.

Okafor, G.I., Usman, G.O. (2014). Production and evaluation of breakfast cereals from blends of African yam bean (*Sphenostylis stenocarpa*), maize (*Zea mays*) and defatted coconut (*Cocus nucifera*). *Journal of Food Processing and Preservation*, 38: 1037-1043.

Oszmiański, J., Wojdylo, A. (2005). *Aronia melanocarpa* phenolics and their antioxidant activity. *European Food Research and Technology*, 221: 809-813.

Paucean, A., Man, S., Muste, S., Pop, A. (2017). Development of gluten free cookies from rice and coconut flour blends. *Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca-Food Science and Technology*, 73 (2): 163-164.

Ramaswamy, L. (2014). Coconut flour - a low carbohydrate, gluten free flour a review article. *International Journal of Ayurvedic and Herbal Medicine*, 4 (1): 1426-1436.

Ramírez-Maganda, J., Blancas-Benítez, F.J., Zamora-Gasga, V.M., García-Magaña, M.L., Bello-Pérez, L.A., Tovar, J., Sáyago-Ayerdi, S.G. (2015). Nutritional properties and phenolic content of a bakery product substituted with a mango (*Mangifera indica*) 'Ataulfo' processing by-product. *Food Research International*, 73: 117-123.

Ribotta, P.D., Colombo, A., Rosell, C.M. (2012). Enzymatic modifications of pea protein and its application in protein–cassava and corn starch gels. *Food Hydrocolloids*, 27 (1): 185-190.

Rodríguez-Werner, M., Winterhalter, P., Esatbeyoglu, T. (2019). Phenolic composition, radical scavenging activity and an approach for authentication of *Aronia melanocarpa* berries, juice, and pomace. *Journal of Food Science*, 84 (7): 1791-1798.

Sabença, C., Ribeiro, M., de Sousa, T., Poeta, P., Bagulho, A.S., Igrejas, G. (2021). Wheat/gluten-related disorders and gluten-free diet misconceptions: A review. *Foods*, 10: 1765-1789.

Sapone, A., Bai, J.C., Ciacci, C., Dolinsek, J., Green, P.H.R., Hadjivassiliou, M., Kaukinen, K., Rostami, K., Sanders, D.S., Schumann, M., Ullrich, R., Villalta, D., Volta, U., Catassi, C., Fasano, A. (2012). Spectrum of gluten-related disorders: consensus on new nomenclature and classification. *BMC Medicine*, 10:13.

Šmídová, Z., Rysová, J. (2022). Gluten-free bread and bakery products technology. *Foods*, 11: 480.

Sun, Y., Hayakawa, S., Ogawa, M., Izumori, K. (2007). Antioxidant properties of custard pudding dessert containing rare hexose, D-psicose. *Food Control*, 18: 220-227.

Szajnar, K., Pawlos, M., Znamirowska, A. (2021). The effect of the addition of chokeberry fiber on the quality of sheep's milk fermented by *Lactobacillus rhamnosus* and *Lactobacillus acidophilus*. *International Journal of Food Science*, 2021: 7928745.

Tovoli, F., Masi, C., Guidetti, E., Negrini, G., Paterini, P., Bolondi, L. (2015). Clinical and diagnostic aspects of gluten related disorders. *World Journal of Clinical Cases*, 3 (3): 275-284.

Trinidad, T.P., Mallillin, A.C., Valdez, D.H., Loyola, A.S., Askali-Mercado, F.C., Castillo, J.C., Encabo, R.R., Masa, D.B., Maglaya, A.S., Chua, M.T. (2006). Dietary fiber from coconut flour: A functional food. *Innovative Food Science and Emerging Technologies*, 7: 309-317.

Usman, G.O., Okafor, G.I. (2016). Organoleptic properties and perception of maize, African yam bean, and defatted coconut flour-based breakfast cereals served in conventional forms. *Food Science and Nutrition*, 4 (5): 716-722.

Valencia, M.S., Salgado, S.M., Andrade, S.A.C., Padilha, V.M., Livera, A.V.S., Stamford, T.L.M. (2016). Development of creamy milk chocolate dessert added with fructooligosaccharide and *Lactobacillus paracasei* subsp. *paracasei* LBC 81. *LWT-Food Science and Technology*, 69: 104-109.

Vidović, S., Ramić, M., Ambrus, R., Vladić, J., Szabó-Révész, P., Gavarić, A. (2019). Aronia berry processing by spray drying: from by product to high quality functional powder. *Food Technology and Biotechnology*, 57 (4): 513-524.